Stationary wave prediction – Coupled global model research toward improved prediction for week 3-4 and month 2-9 from NOAA

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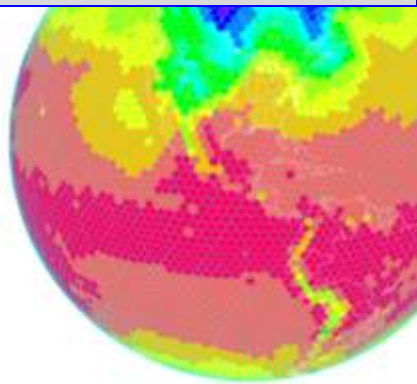
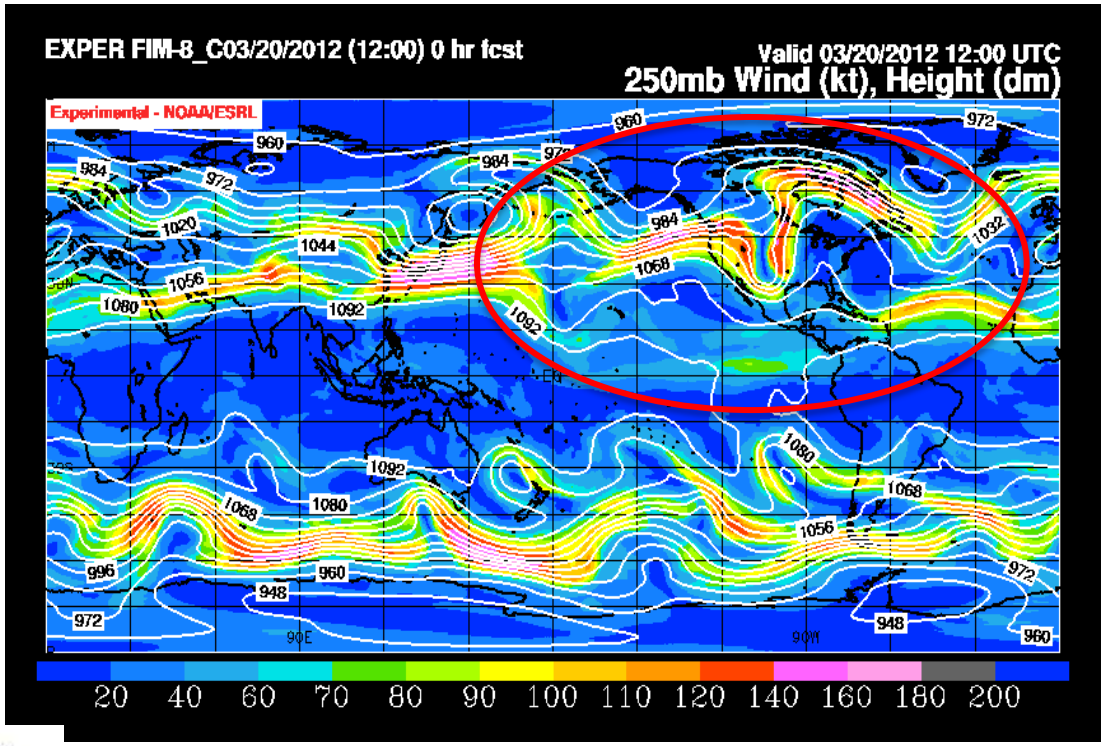




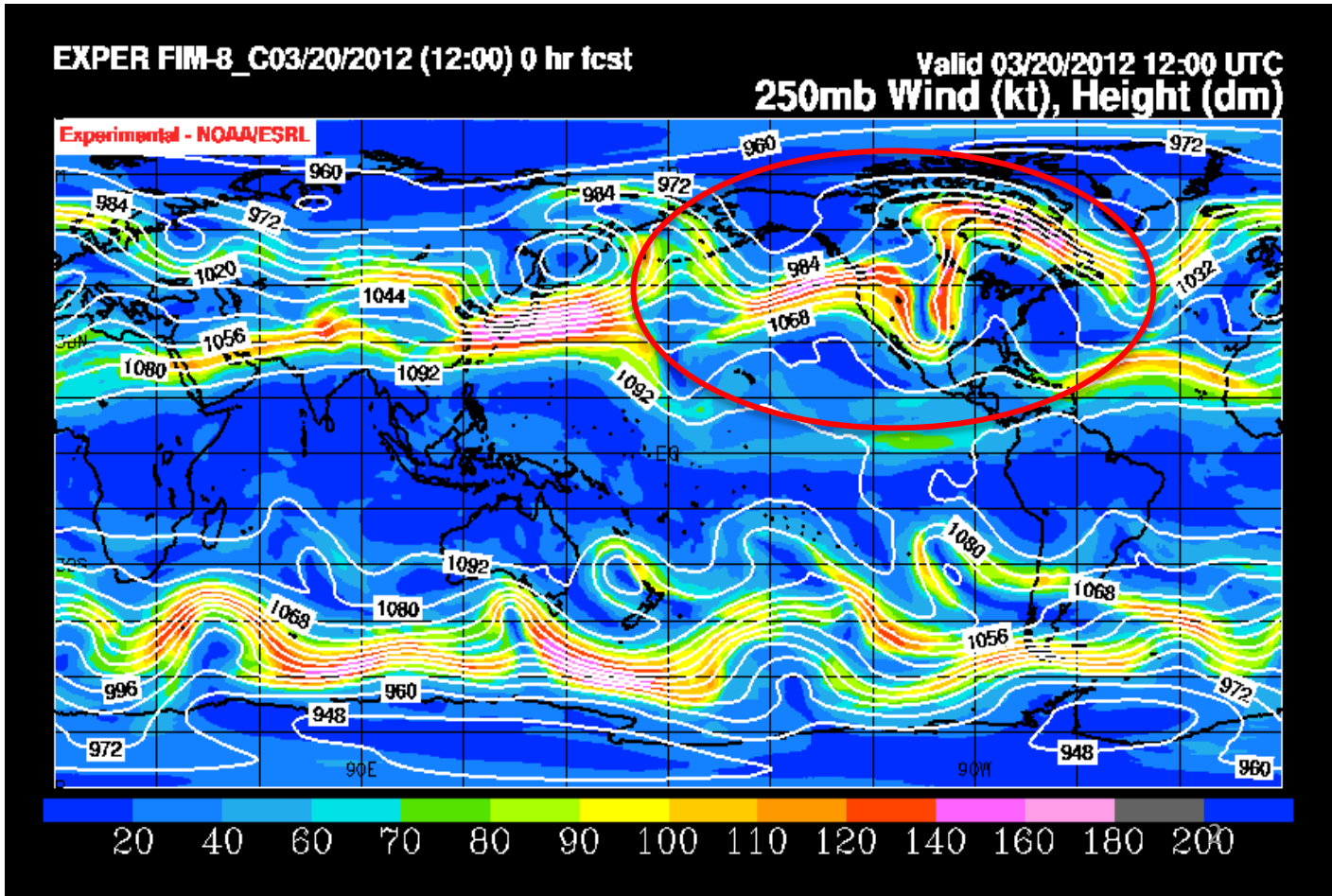
March 2012 N. American block

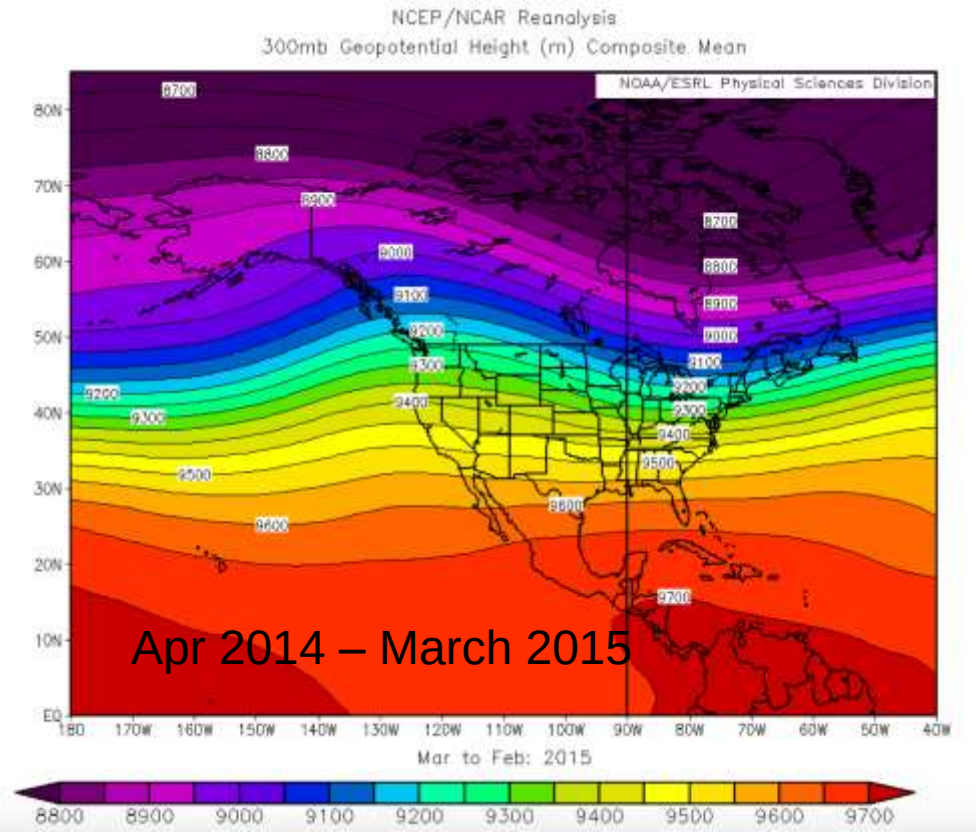
Episodic Weather Extremes from Blocking

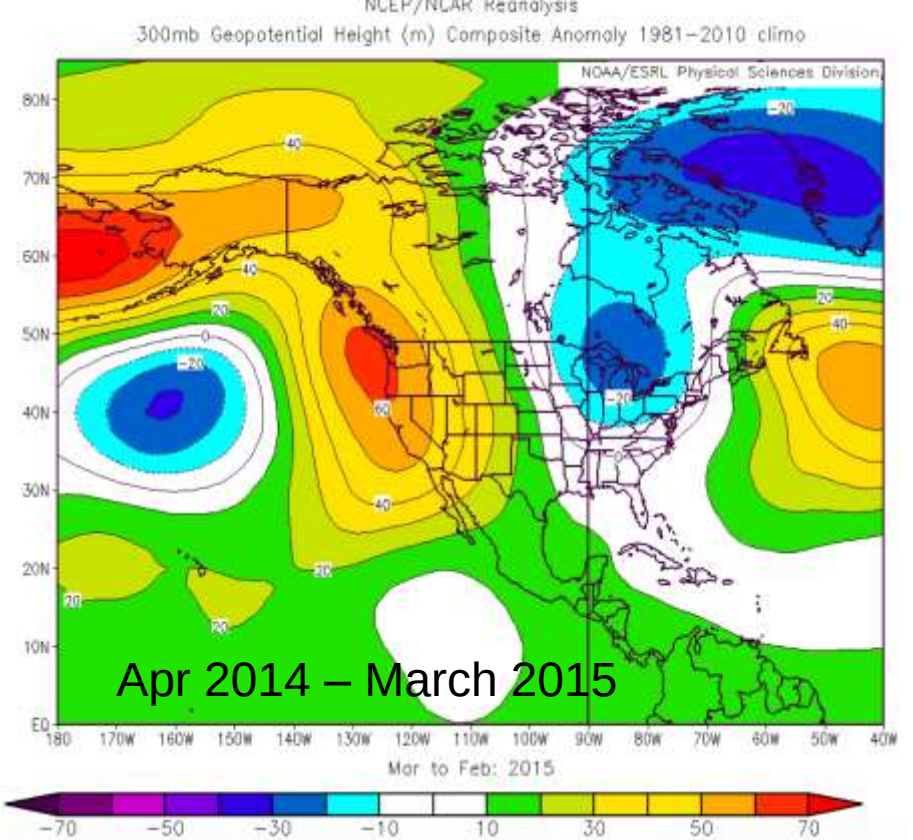
Longer-term weather anomalies from atmospheric blocking -Defined here as either ridge or trough quasi-stationary events with duration of at least 4 days to 2+ months

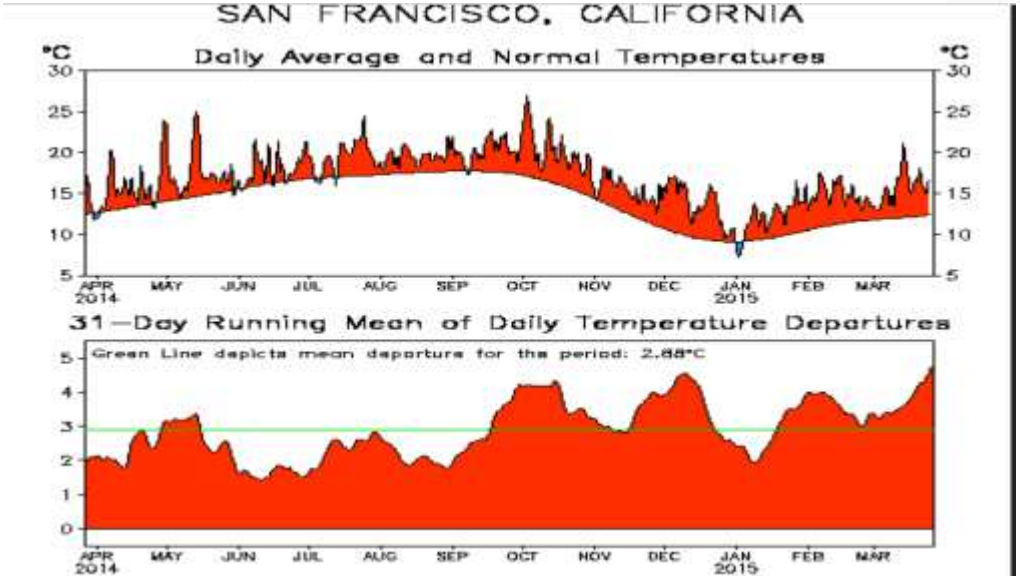
ESPC focus area #1

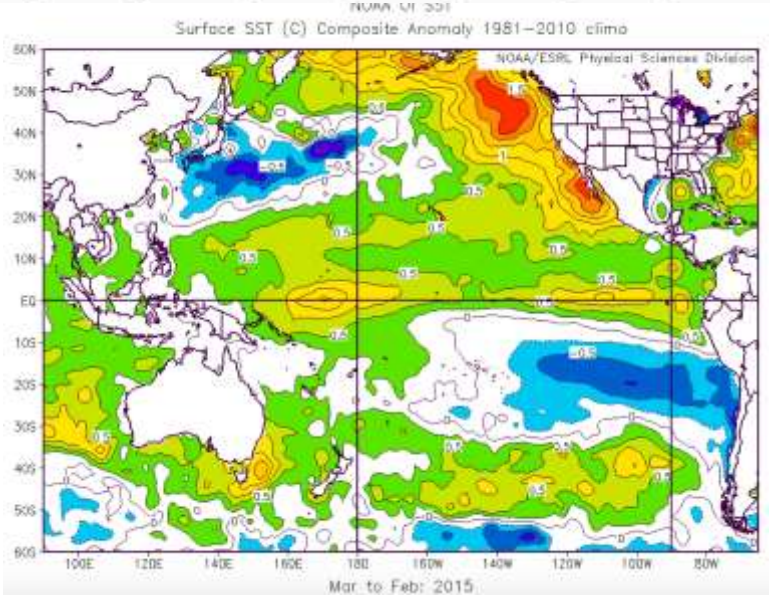
target: improved 0.5-6 month forecasts of blocking and related weather extremes




NCEP/NCAR Reanalysis
300mb Geopotential Height (m) Composite Mean
NOAA/ESRL Physical Sciences Division
Apr 2014 – March 2015
Mar to Feb: 2015
8800 8900 9000 9100 9200 9300 9400 9500 9600 9700

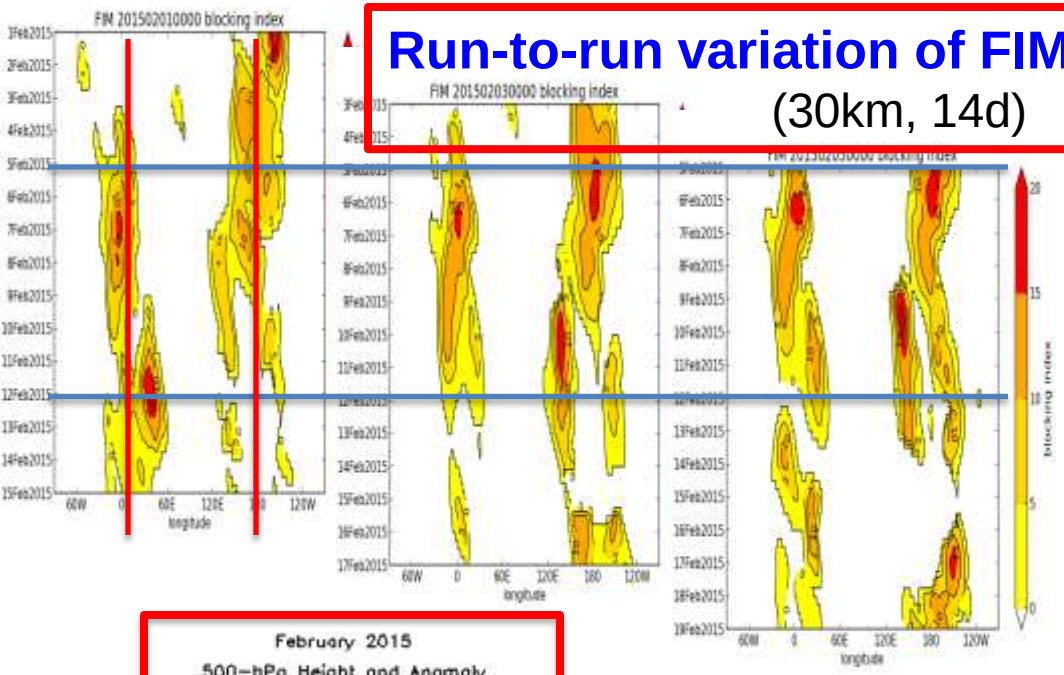

NCEP/NCAR Reanalysis
300mb Geopotential Height (m) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division
Apr 2014 – March 2015
Mar to Feb: 2015
−70 −50 −30 −10 10 30 50 70


SAN FRANCISCO, CALIFORNIA
Daily Average and Normal Temperatures
°C
APR 2014 MAY JUN JUL AUG SEP OCT NOV DEC JAN 2015 FEB MAR
31-Day Running Mean of Daily Temperature Departures
Green Line depicts mean departure for the period: 2.88°C

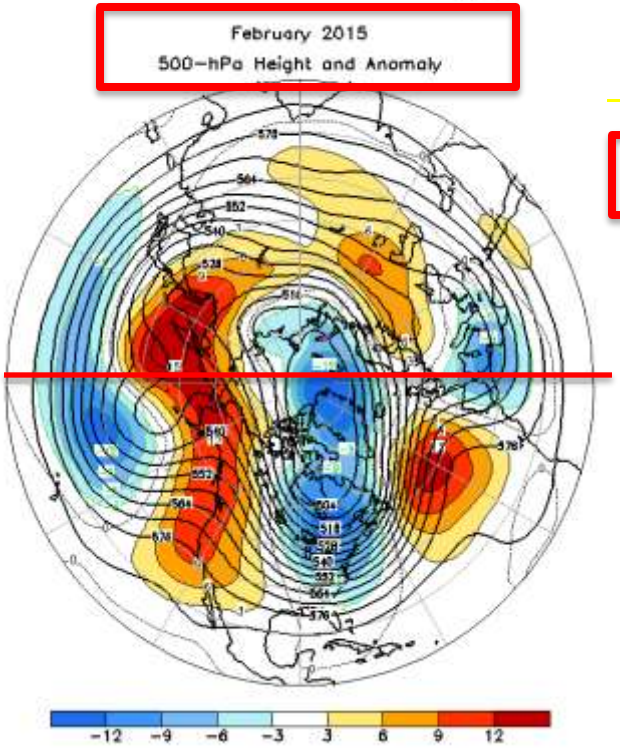

Surface SST (C) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division
Mar to Feb: 2015

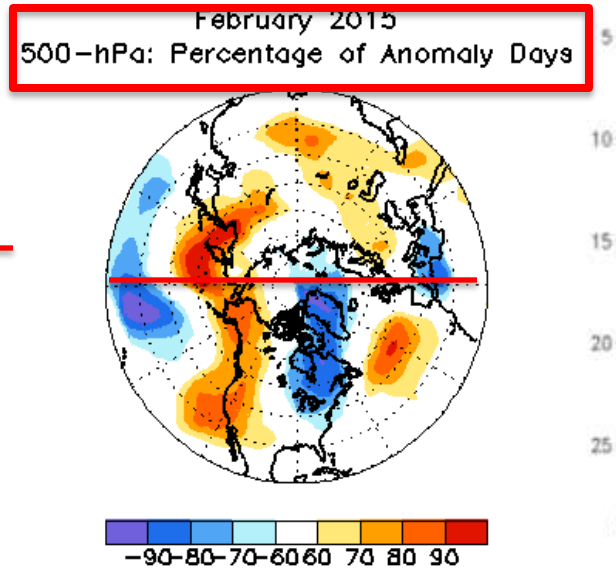
Run-to-run variation of FIM blocking (Tibaldi-Molteni)

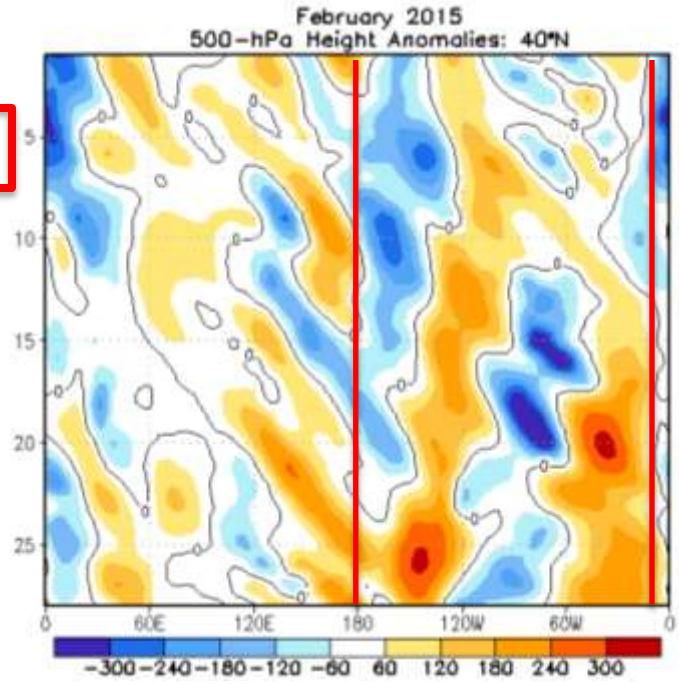
(30km, 14d)



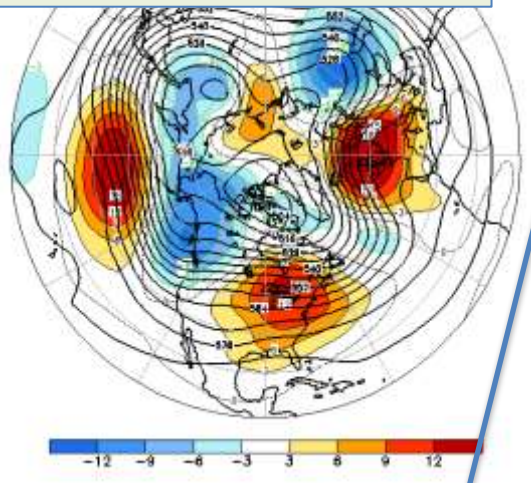
Stationary wave depiction – Feb 2015







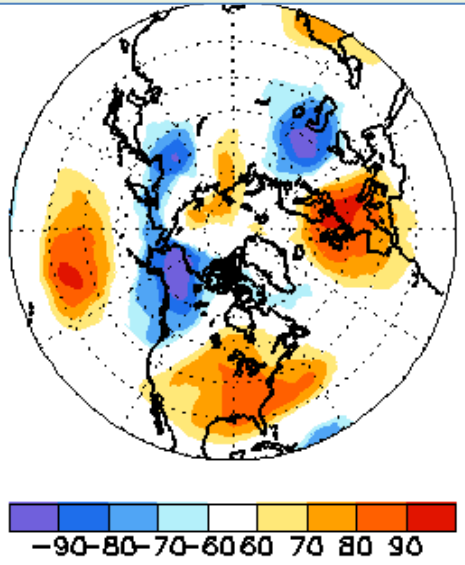
Mean 500z anomaly
Mar 2012

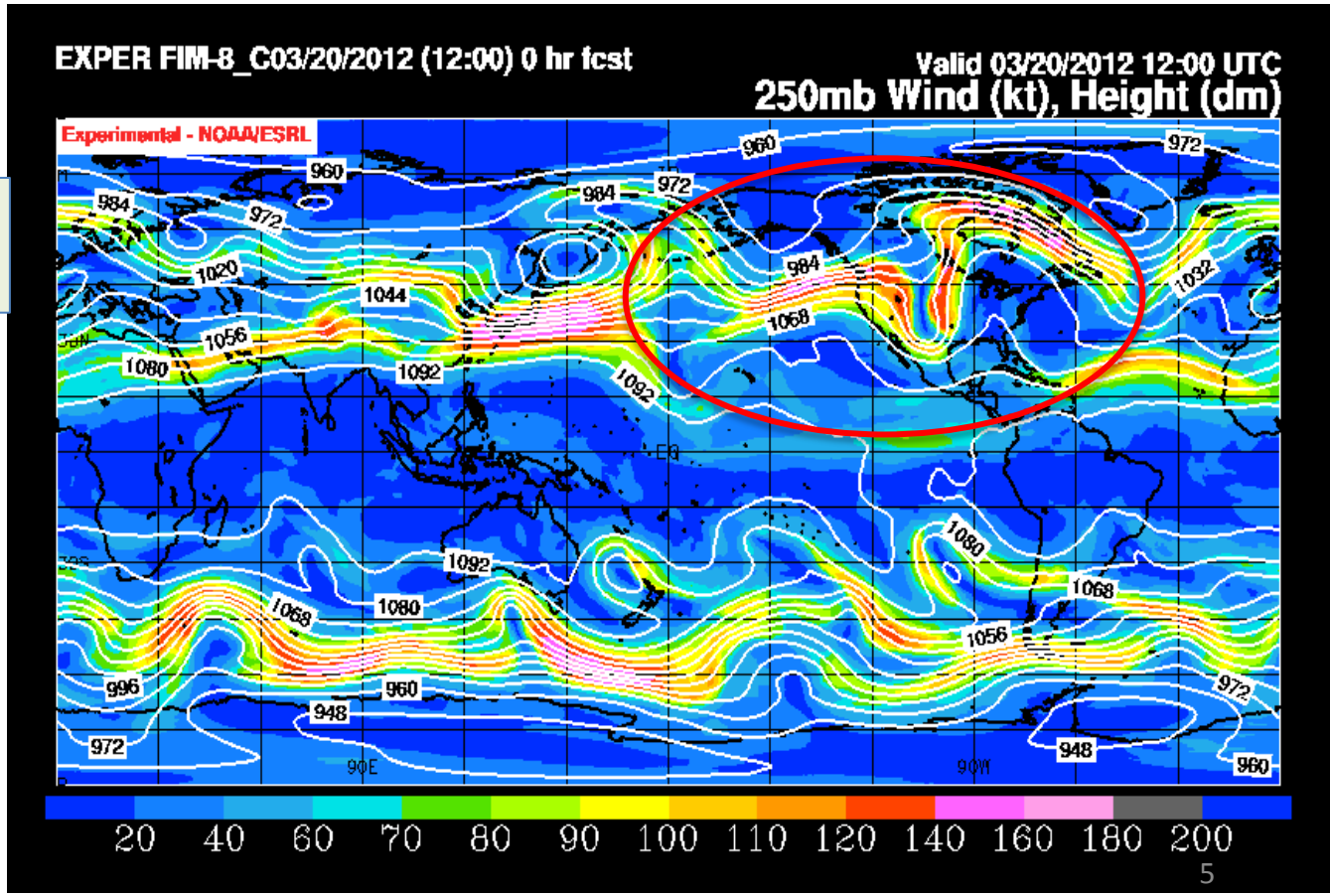


Stationary Wave Metric: % of 500hPa height anomaly days per month

- Useful complement to blocking per Tibaldi-Molteni (or Pelly-Hoskins)
- Broader, focuses on daily consistency

% of anomaly days/mon
Mar 2012





NOAA/Navy/others Earth System Prediction Capability
ESPC focus target: improved 1-6 month fcst of blocking

Processes related to blocking onset, cessation, prolongation

- Extratropical wave interaction
- MJO life cycle
- Other tropical procs/ENSO
- Tropical storms and their extratropical transitions
- Sudden strato warming events
- Snow cover anomalies
- Soil moisture anomalies
- Cloud/radiation/temp patterns (avoid regions of SST bias, continental warm bias, etc.)

Model component sensitivity

Initial value - data assim	High-res Δx	Coupled ocean	Stochastic phys	Cloud/rad phys	PV cons. numerics	Chem/aerosol	Soil/snow LSM accuracy
▯	▯		▯		▯		
▯	▯	▯	▯		▯	▯	
▯	▯	▯	▯			▯	
▯	▯	▯	▯		▯	▯	▯
▯					▯	▯	
▯						▯	▯
▯		▯		▯		▯	▯
				▯			

Blocking frequency as a function of global model resolution

Jung et al., 2012, *J. Climate*: High-res ECMWF experiments for **Project ATHENA**

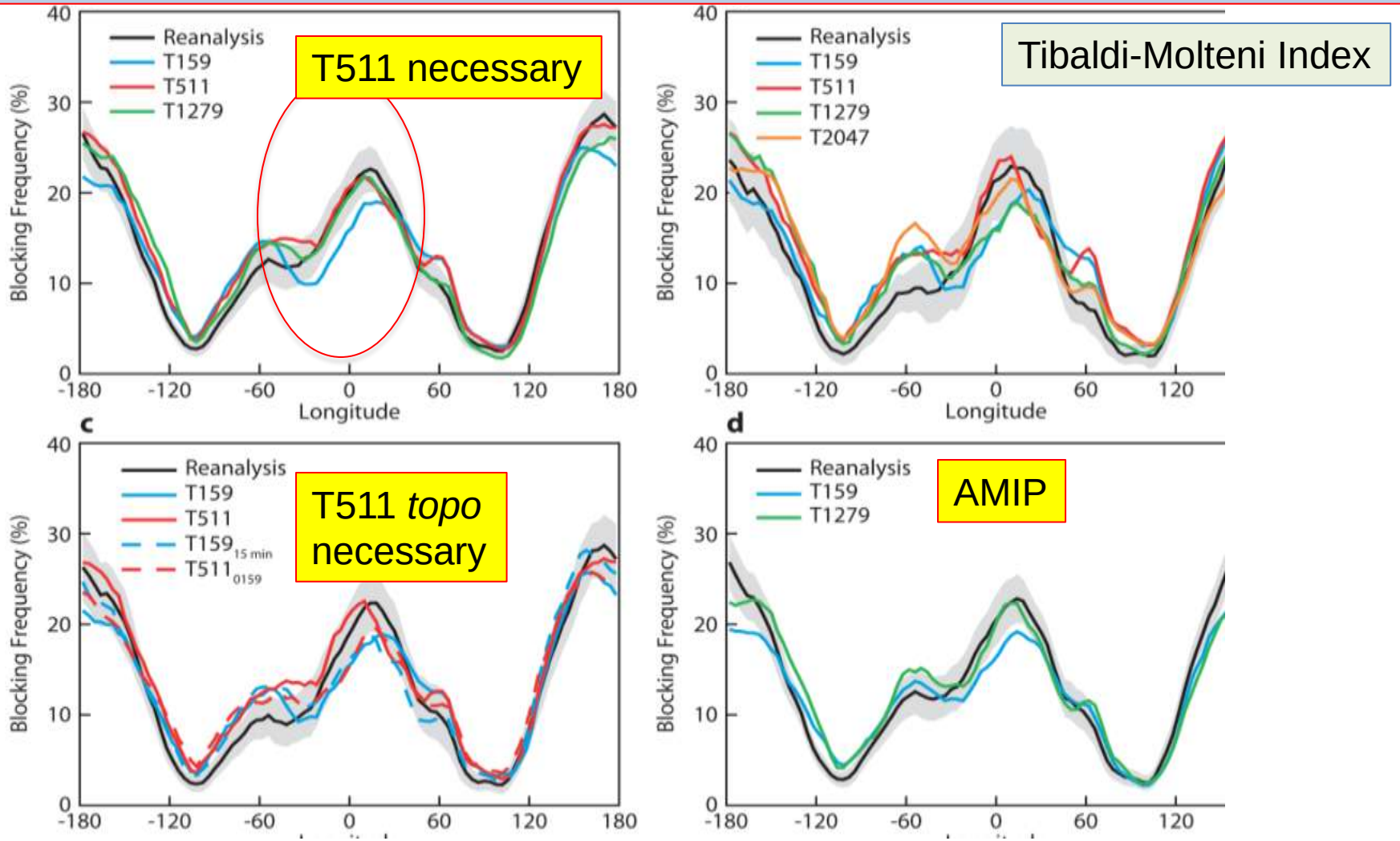


FIG. 8. Frequency of occurrence (in %) of days at which the wintertime (December–March) Northern Hemisphere midlatitude flow is blocked: (a) ERA reanalysis (black with 95% confidence level using a two-sided Student's *t* test), T159 (blue), T511 (red), and T1279 (green) for the period 1960/61–2007/08. (b) As in (a), but for the shorter period 1989/90–2007/08 and with T2047 results (orange) included. Results in (a) and (b) are based on 13-month integrations. (c) As in (a), but for the period 1980/81–2007/08 and at T159 (blue), T511 (red), $T159_{15min}$ (dashed blue), and $T511_{O159}$ (dashed red). (d) As in (a), but for AMIP-style experiments and the shorter period 1962/63–2006/07.

Key research questions for stationary waves/blocking

1. What is **predictability (using week-month-90day time-averaging) at week-3 to month-9** (NMME range) **duration** of blocking and stationary waves from **existing global model**s (especially GFS and CFSv2, FIM-iHYCOM, NMME models)?
2. What is the **minimum horizontal and vertical resolution** needed for global models to capture blocking events and associated processes?
   - Identify sensitivity to model numerics as well as resolution.
3. To what extent is **accurate prediction of the following phenomena** necessary for predicting onset/cessation of stationary wave events?
   - MJO, stratospheric warming events?
   - Subtropical jets (existence, preservation)?
   - Tropospheric Rossby wave-breaking?
4. To what extent is over- or under-prediction of blocking dependent on model physics suite? (e.g., formation – deep convection? decay – primarily radiation?)

Study key stationary wave/blocking events

(candidate periods)

- Spring 2011 vs. spring 2012 – March-June 2012 has a strong persistent ridge over eastern North America (Dole et al. 2013, BAMS). By contrast, spring 2011 had similar La Nina conditions but without any similar extended blocking in the Northern Hemisphere.
- Winter 2013-2014 – Persistent trough position over eastern North America. (Notable contrast in Great Lakes ice cover – record-breaking winter vs. winter 2011-2012 with very little ice cover). (Or Jan-Mar 2015!)
- Summer 2010 – Persistent ridging over eastern Europe and western Asia (Galarneau et al., 2012, MWR)
- Jan-Feb 2010 – stratospheric sudden warming event
- Nov-Dec 2010 – cold winter in western Europe
- March 2013 – cold month in western Europe and UK
- YOTC (2008-2010), DYNAMO (Oct 2011 – Mar 2012) periods
- 1997-1998 ENSO onset

FIM numerical atmospheric model

- Horizontal grid
  - **Icosahedral,** Δx=240km/120km / 60km/30km/15km/10km
- Vertical grid
  - ptop = 0.5 hPa, θtop ~2200K
  - **Generalized vertical coordinate**
    - **Hybrid θ-σ** option (64L, 38L, 21L options currently)
    - **GFS-like σ-p option** (64 levels)

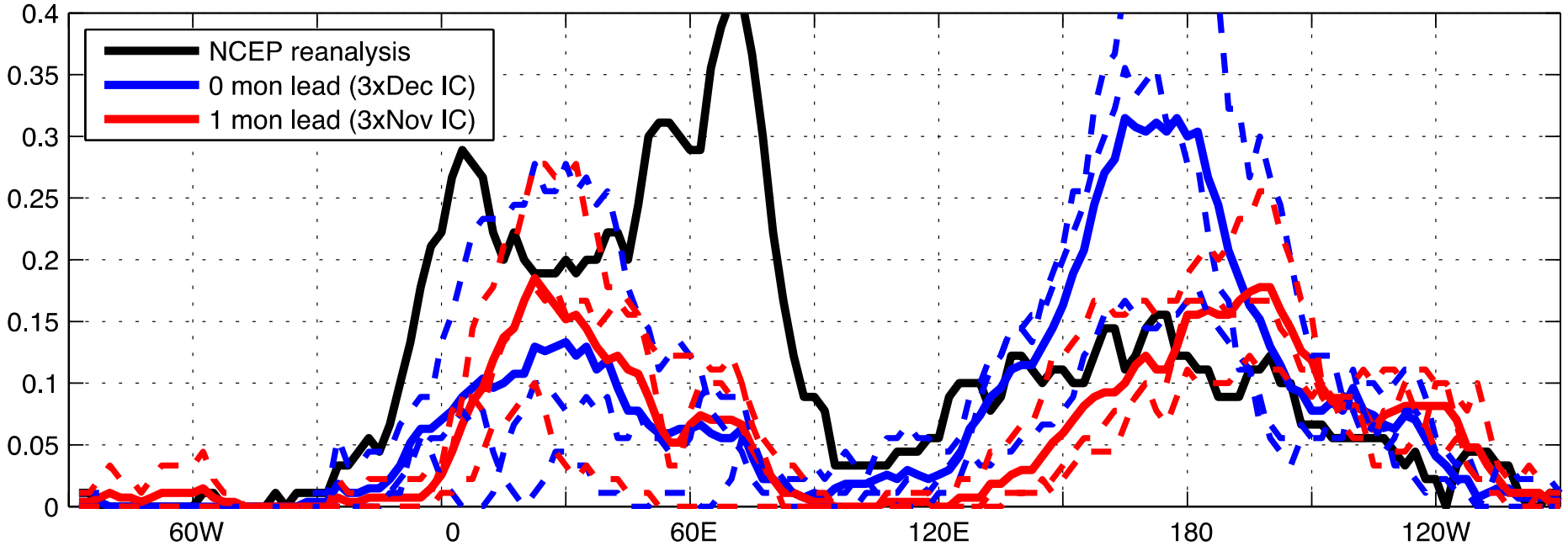
- Physics
  - GFS physics suites
    - May 2011 version, May 2013 McICA radiation),
    - 2015-GFS (incl. "hybrid" EDMF PBL),
    - WRF options esp. Grell-Freitas deep/shallow cumulus
- Coupled model extensions
  - Chem – WRF-chem/GOCART
  - Ocean – icosahedral HYCOM (no coupler), tri-polar HYCOM (with coupler)

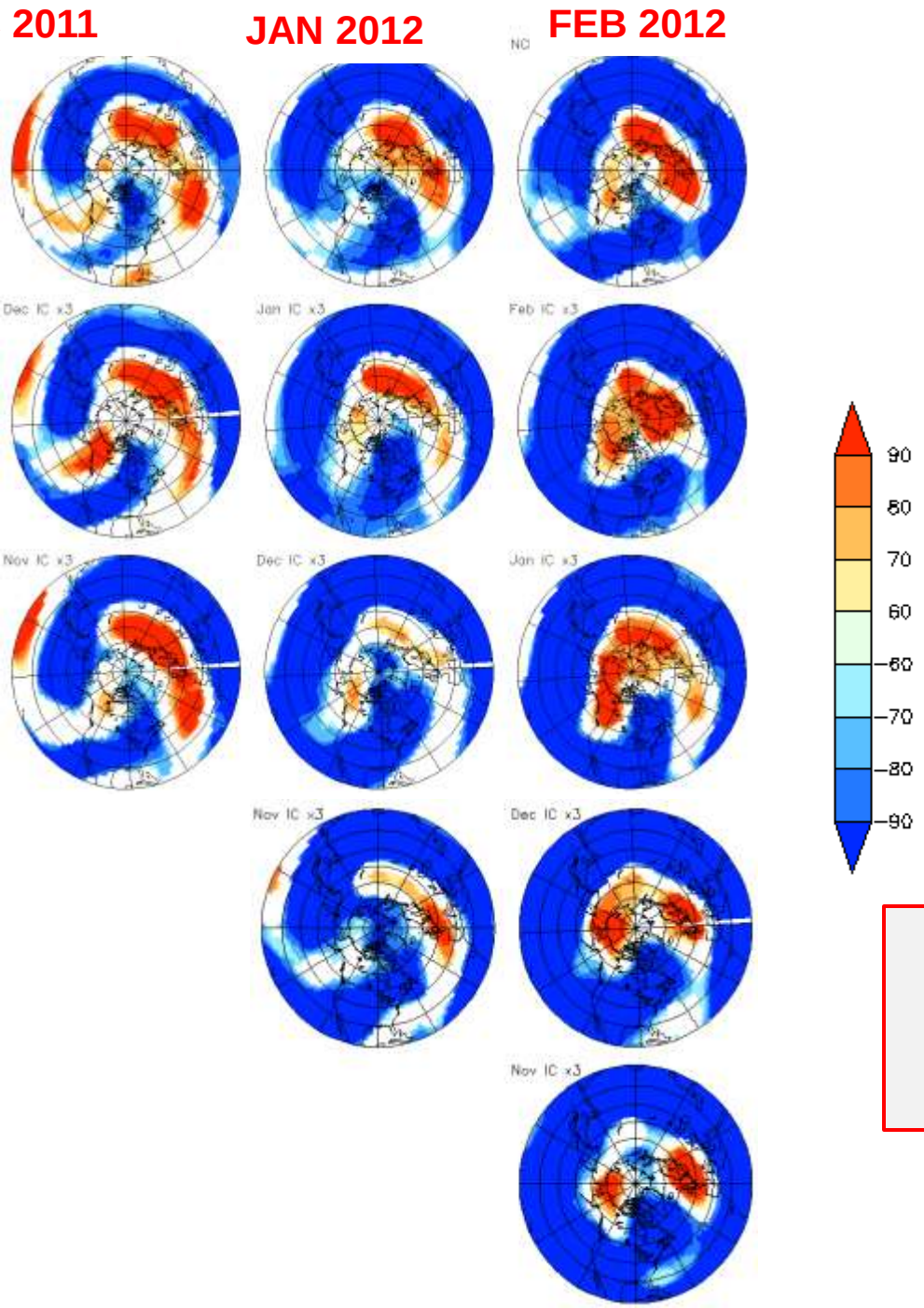
Experiments – CMIP – FIM-HYCOM

- Horizontal resolution: 30km.
- Vertical: Atmos: 64 layers.
    - Ocean: 26 layers
    - Both using vertically adaptive grid
- Physics – atmos: GFS 2015 update physics
- Initial conditions: CFSR atmos & ocean
- Initial time: Dec 11, Jan 12, Feb 12
- Ensemble members 3 for each month
- Forecast duration: 2 months

Evaluation of 2-month forecasts using **Tibaldi-Molteni**-defined blocking

NH blocking frequency – DJF 2011-2012
Coupled FIM-HYCOM – 30km





Evaluation of 3-month forecasts using **%-anom days** to define stat waves

Coupled FIM-HYCOM 30km

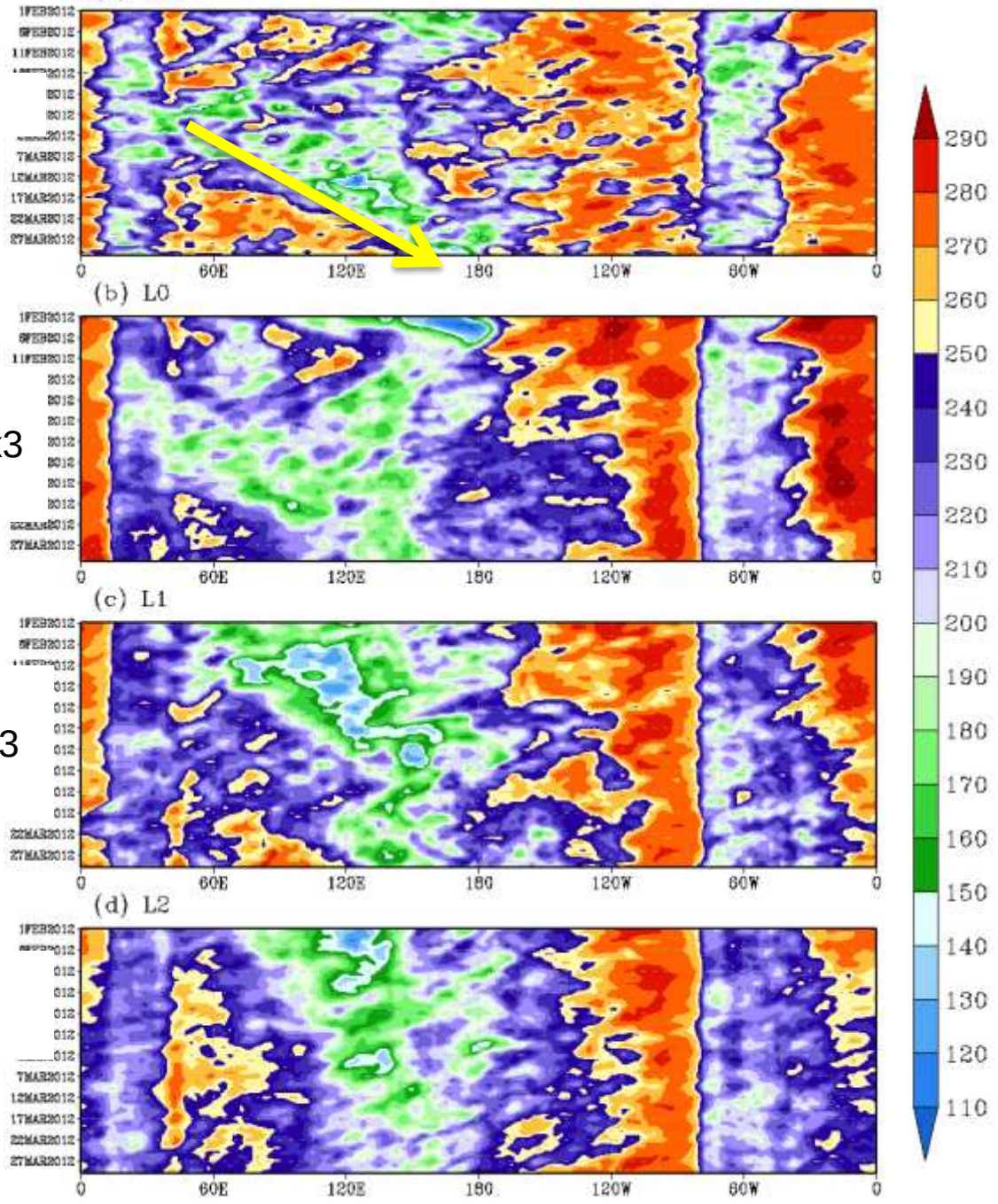
Feb – Mar 2012 TOA outgoing longwave (5°S -15°S average)

observations

0 month lead
Feb 2012 IC x3

1 month lead
Jan 2012 IC x3

2 month lead
Dec 2011 IC
x3



Evaluation of 3-month forecasts for **OLR for MJO** – forcing for stat waves

Coupled FIM-HYCOM 30km

MJO event – OLR

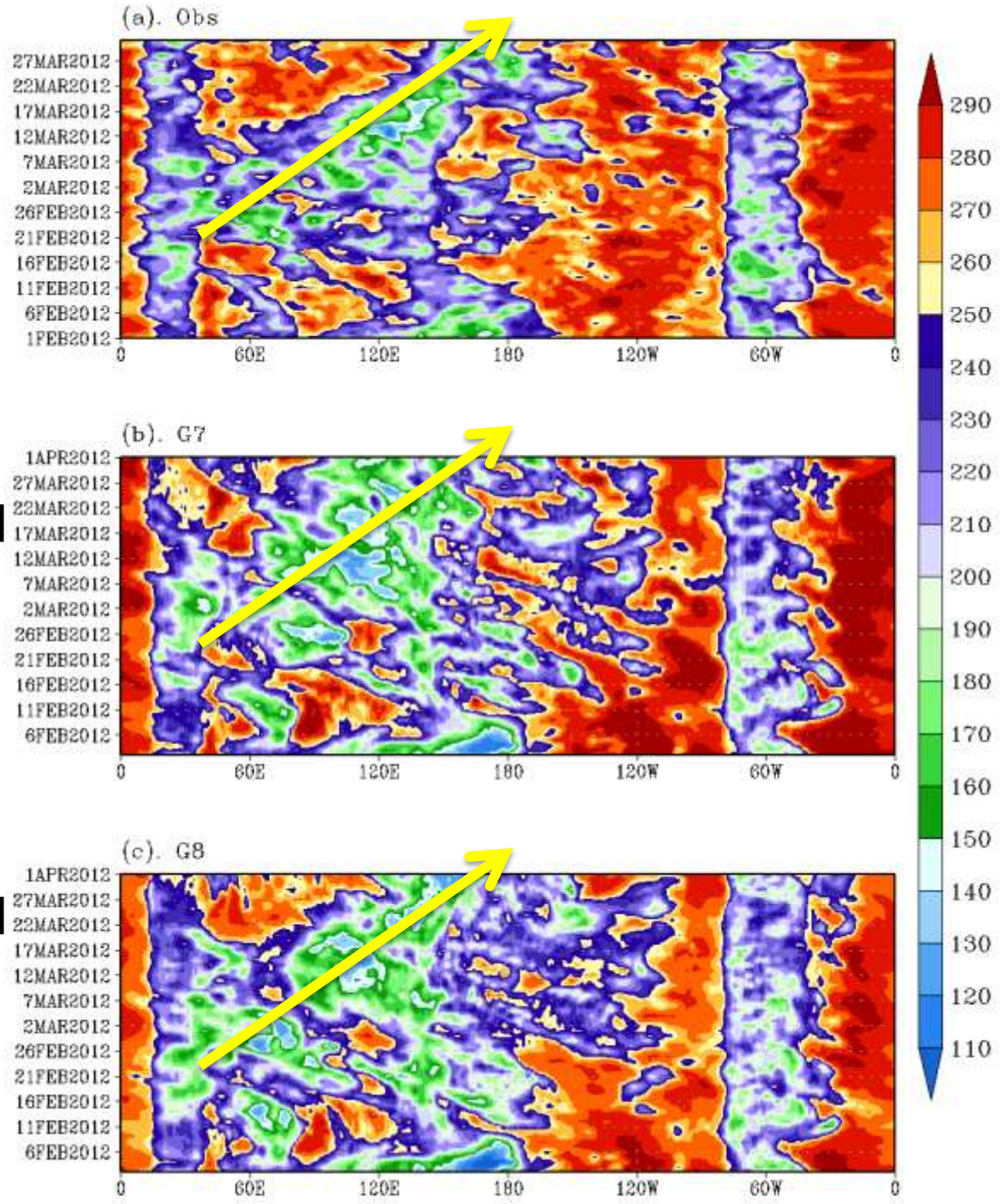
Feb-Mar 2012

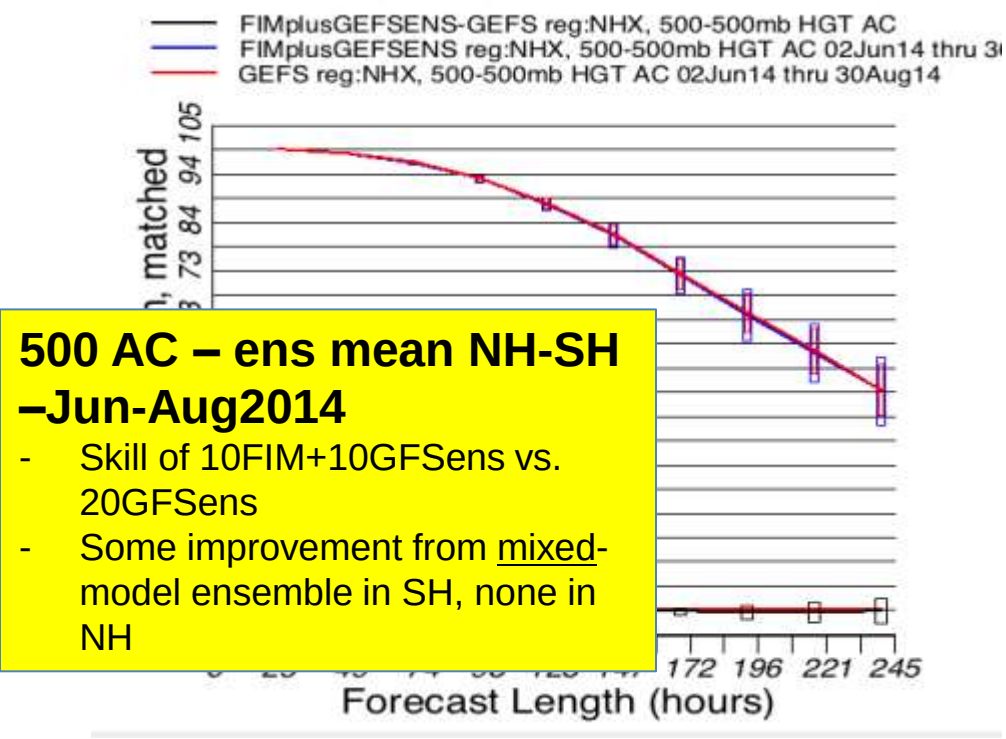
Observed

Coupled FIM-iHYCOM -60km (G7)

Coupled FIM-iHYCOM -30km (G8)

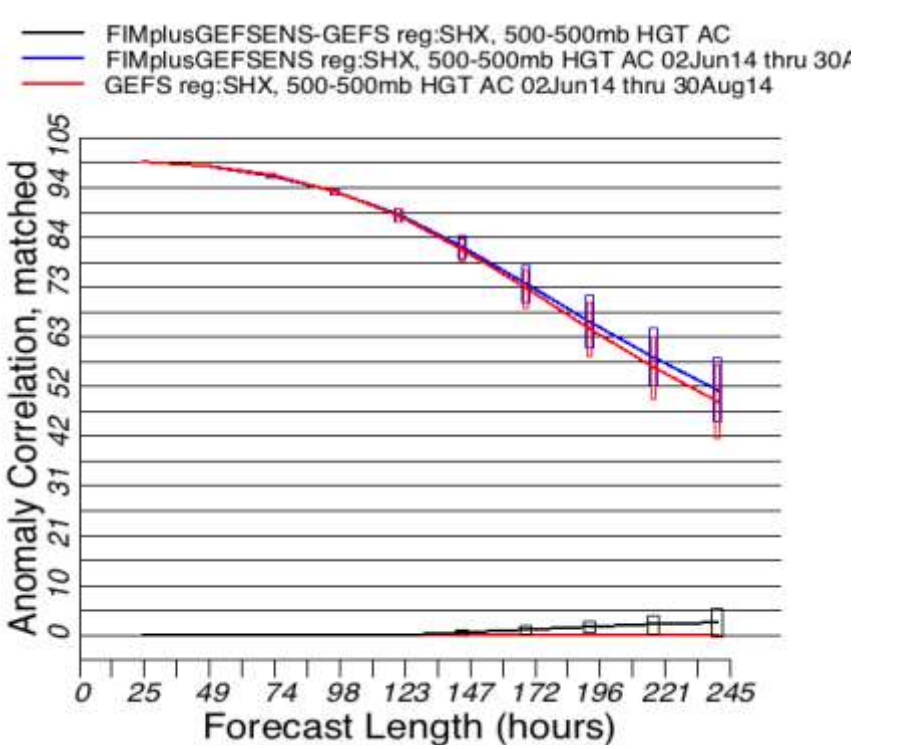
Improved MJO depiction at 30km (vs. 60km)

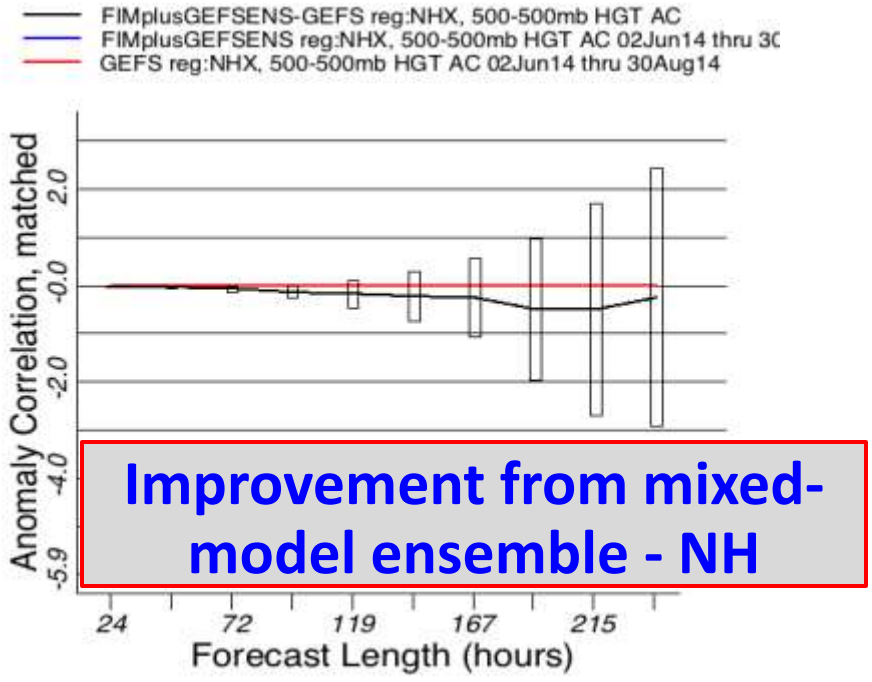




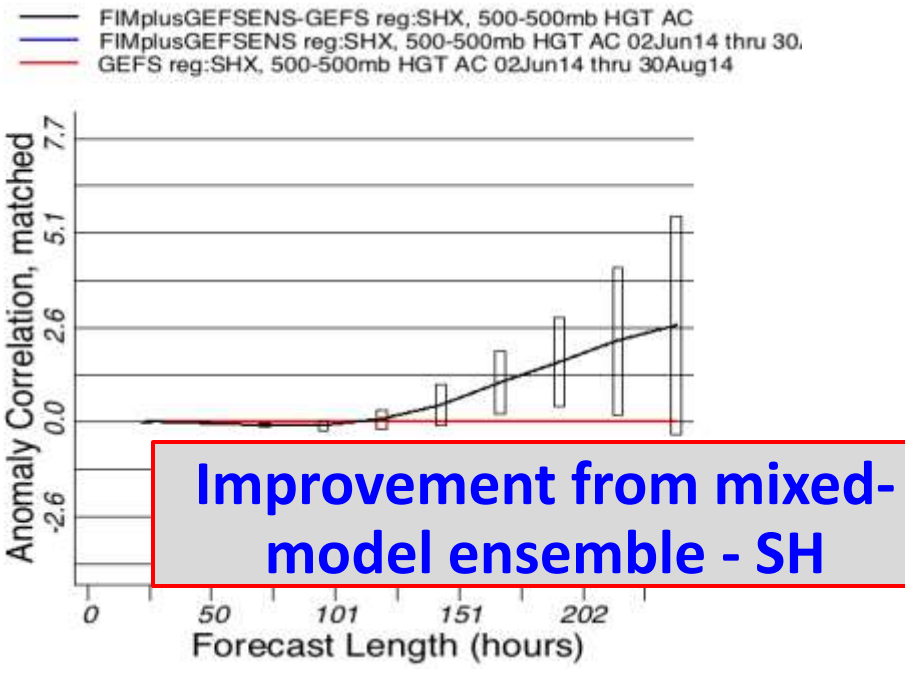
500 AC – ens mean NH-SH –Jun-Aug2014

- Skill of 10FIM+10GFSens vs. 20GFSens
- Some improvement from mixed-model ensemble in SH, none in NH





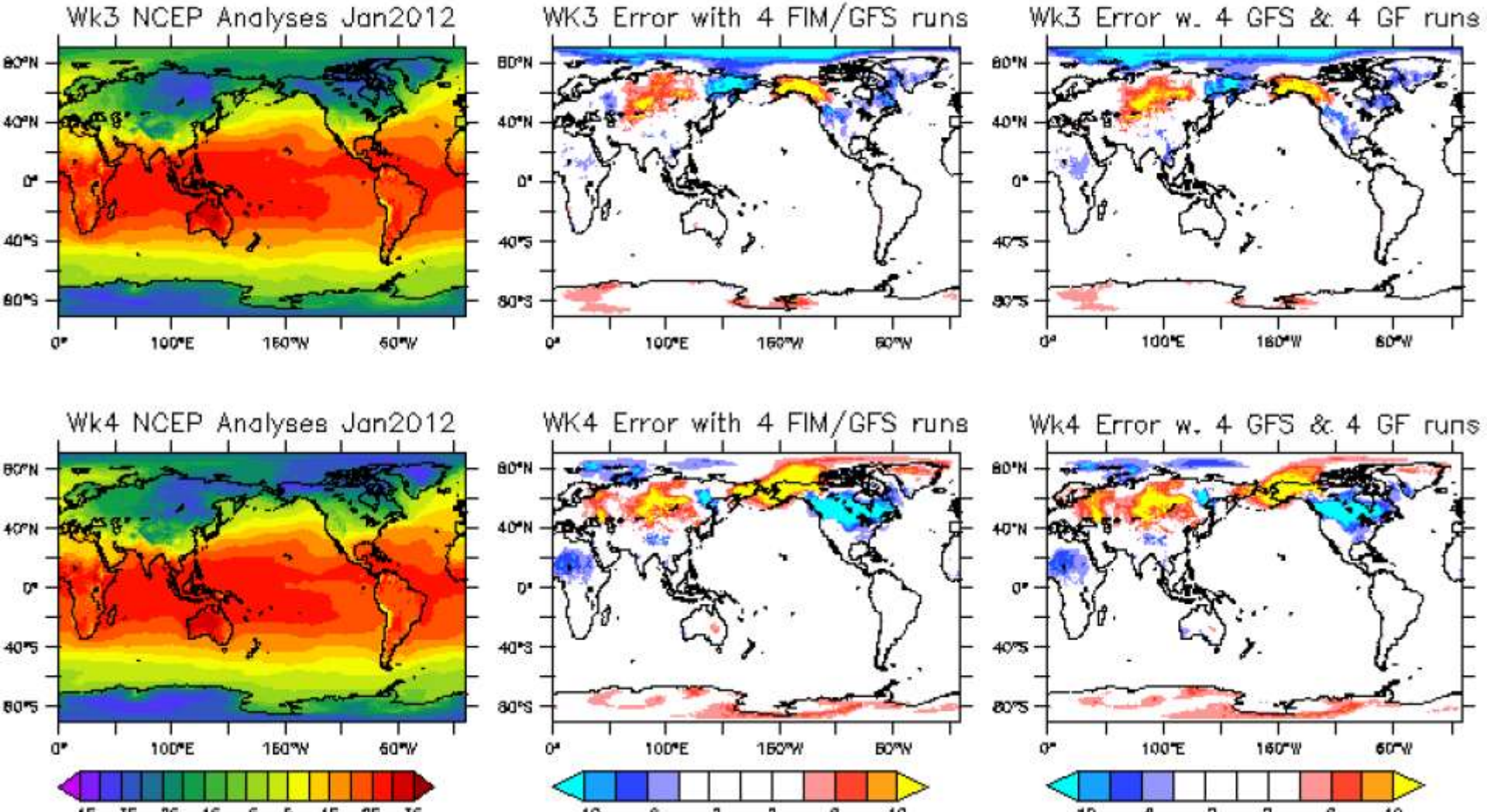
Improvement from mixed-model ensemble - NH



Improvement from mixed-model ensemble - SH

30-day FIM AMIP forecasts (GFS-2011 phys)

3rd & 4th Week 2m Temperature Forecast Error in Jan 2012
NCEP 6h reanalysis = truth

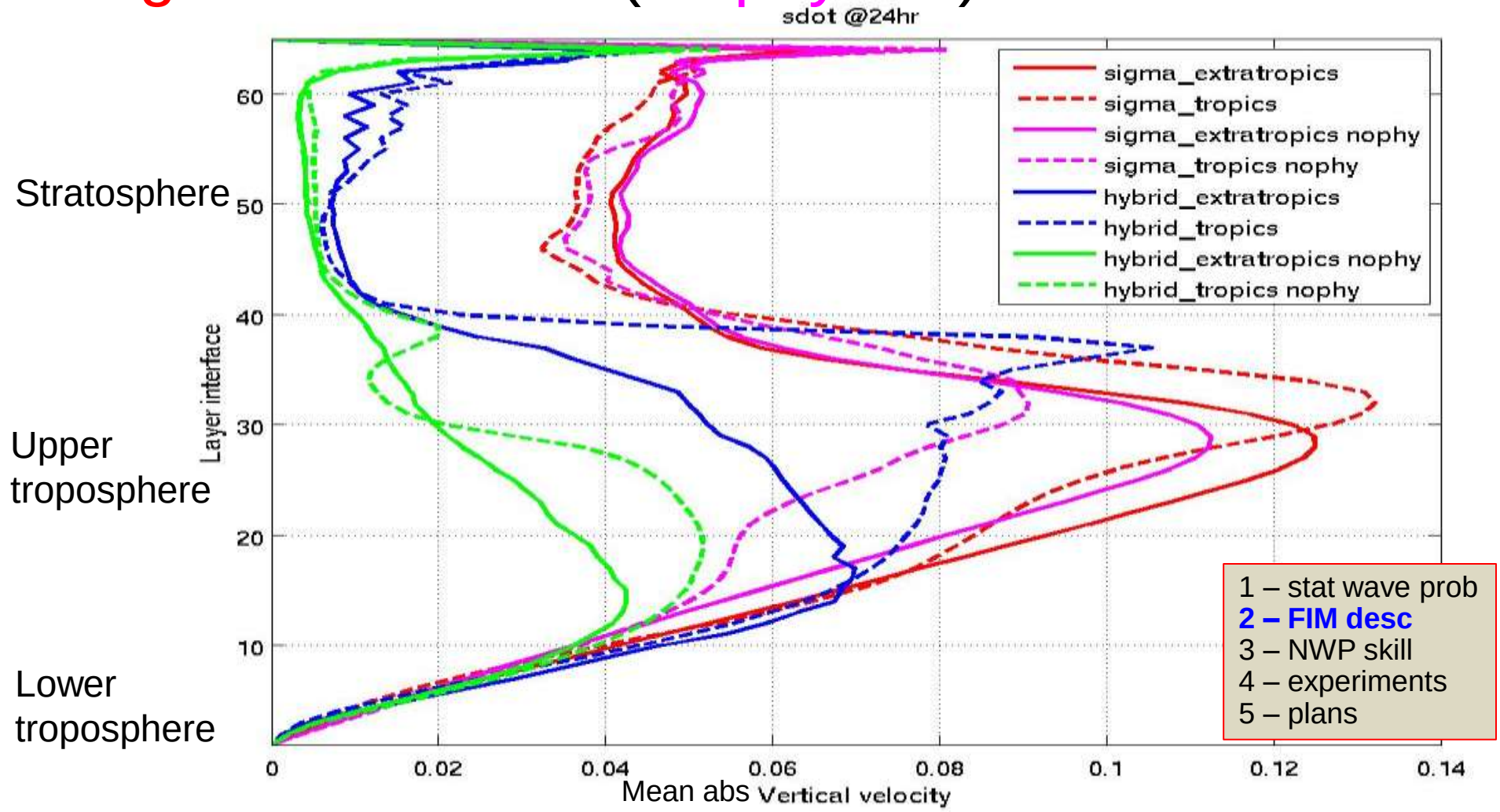


Total 8 60km runs, starting at Jan 01 0z, 6z,12z & 18z, with GFS physics and GF, respectively.

Mean cross-coordinate transport – 24h FIM

quasi-lagrangian hybrid θσ coord (no-physics)

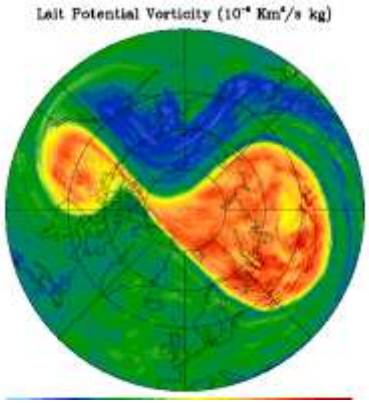
sigma coordinate (no physics)



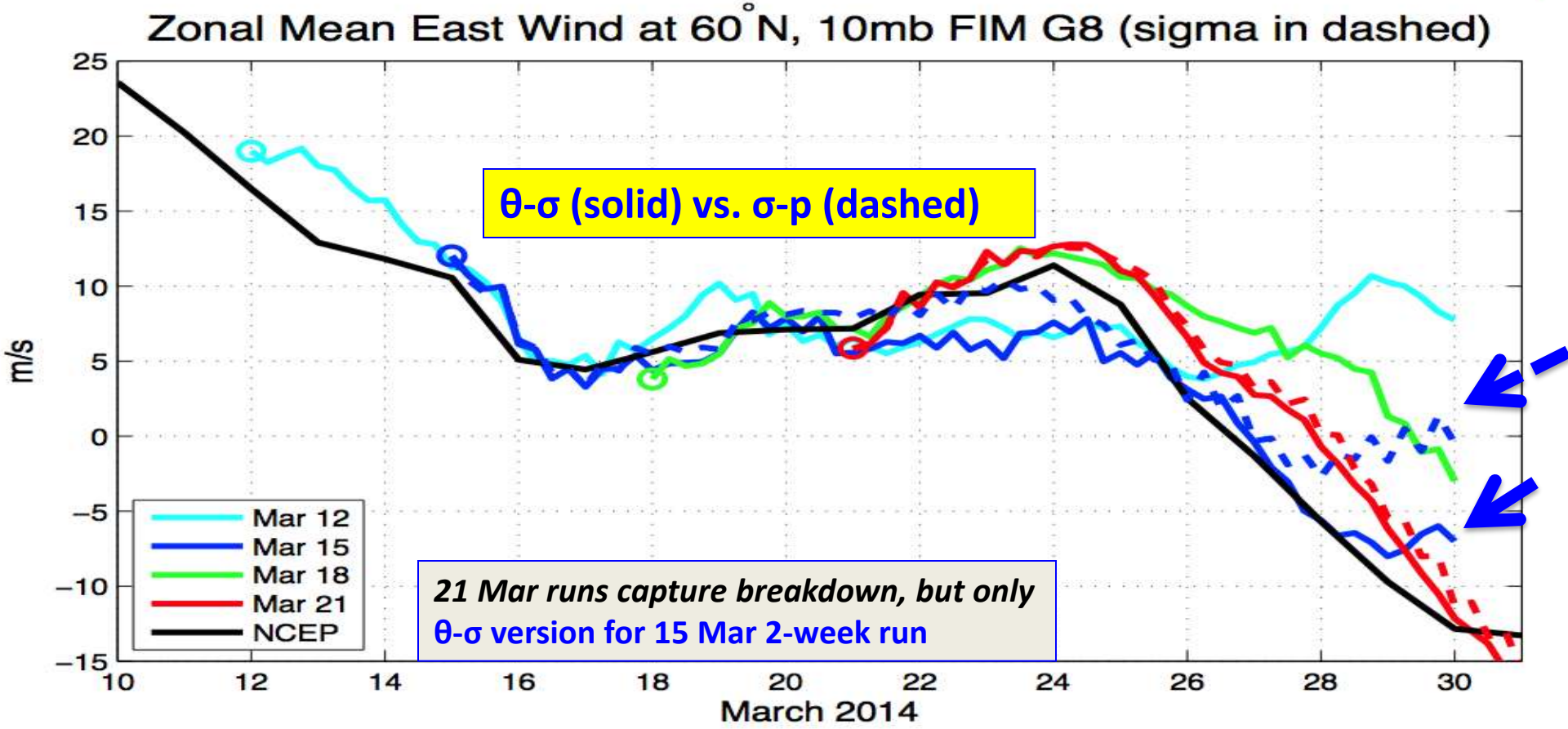
Reduced cross-coord transport (numerical diffusion) with QL θσ vert coord

Stratospheric vortex breakdown

PV on 600K sfc valid 00 UTC 28 Mar 2014



Mean 10hPa zonal wind @60N – Mar2014 – obs vs. FIM fcsts



FIM θ-σ (adaptive) vs. FIM σ-p (fixed) vertical coord

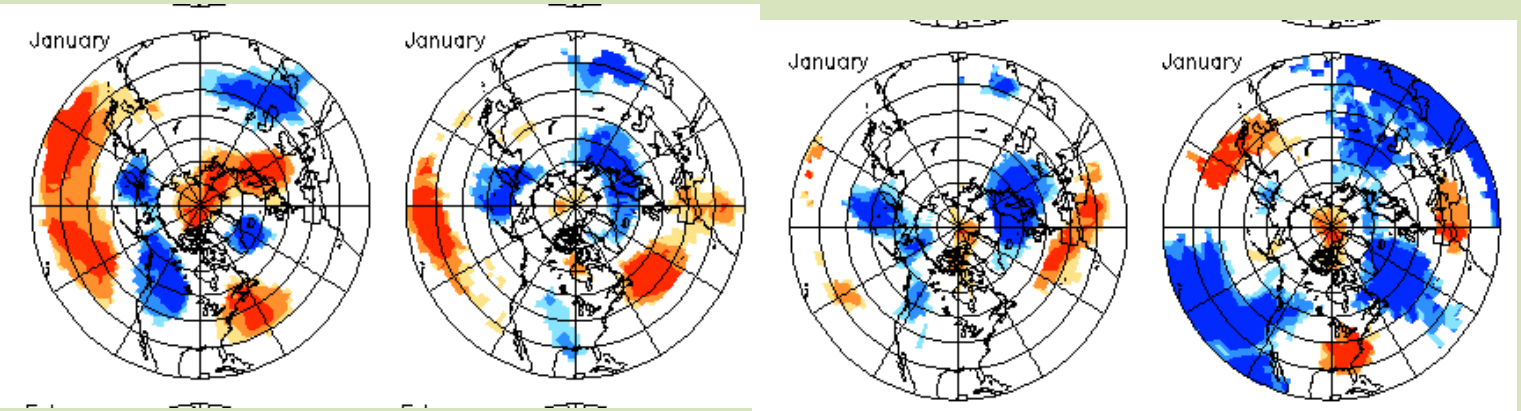
Monthly % of 500 hPa height anomaly days

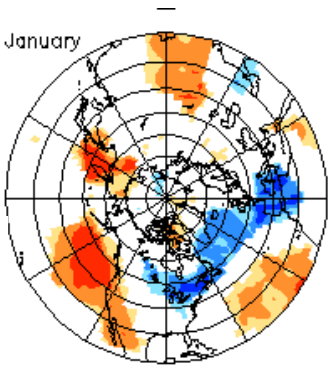
(relative to 30-year mean from Reanalysis)

- **θ-σ** vs. **σ-p** FIM 1-yr AMIP runs – **Jan 2009**

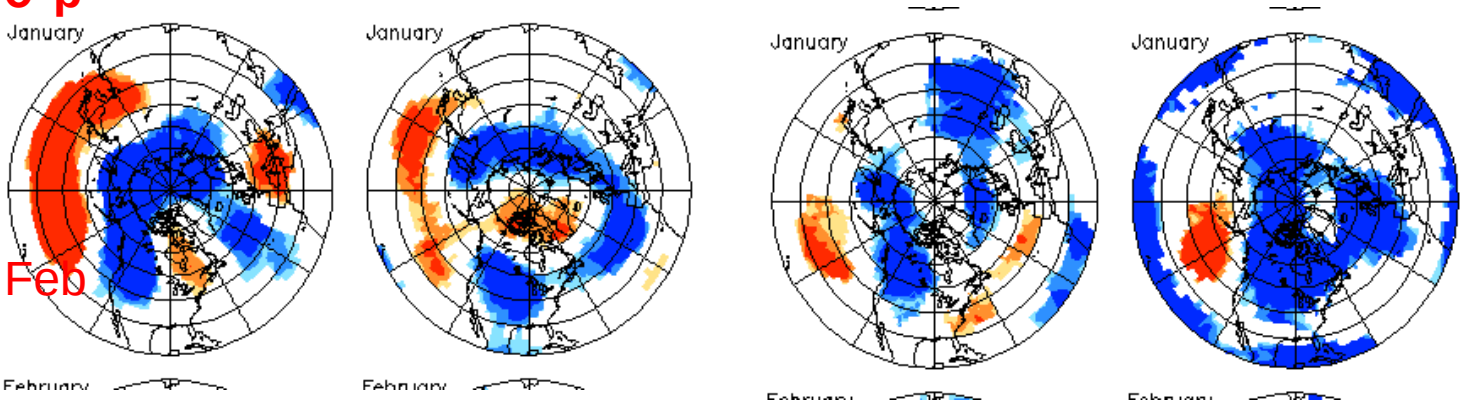
30km 60km 120km 240km Obs

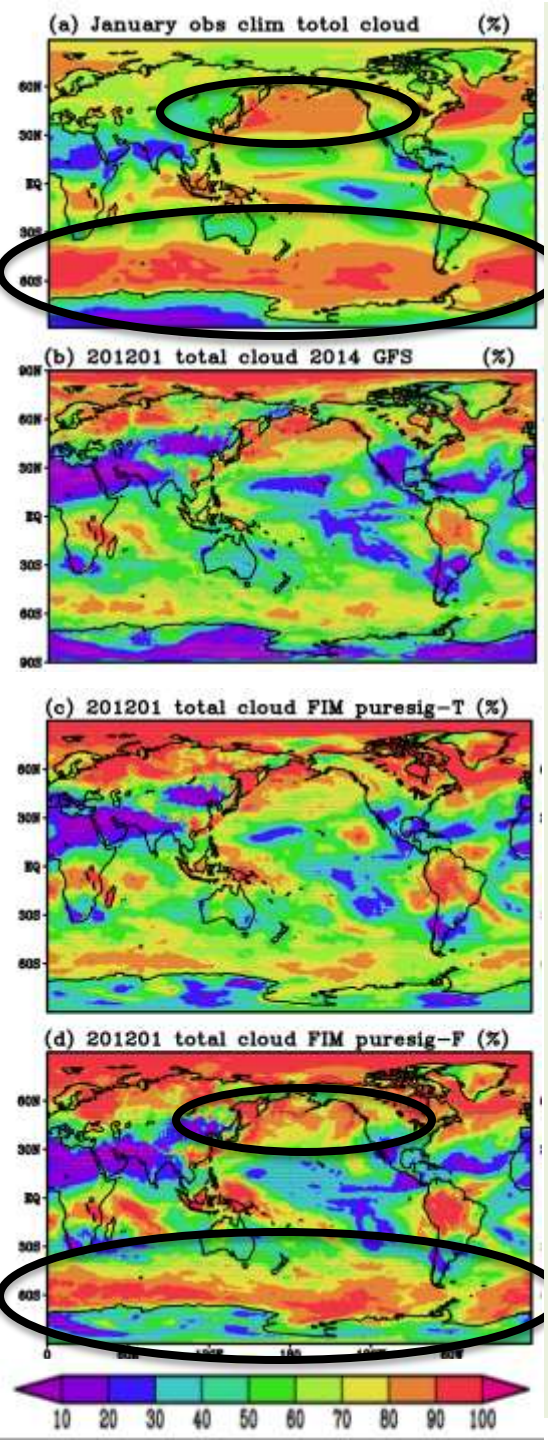
θ-σ





σ-p





1-month – Jan 2012

Obs clouds

GFS with 2014 physics – T574

FIM with GFS-like sigma vert coord

FIM with θ-σ vert coord

Better clouds, critical for coupled application esp. in southern oceans.

2014-15 FIM/ESRL activities toward ESPC

- Continued development of FIM-HYCOM coupled atmos-ocean-chem model
  - Physics, dynamics, ocean
  - Seasonal and NWP evaluation

2015 - Will start NMME hindcast tests soon

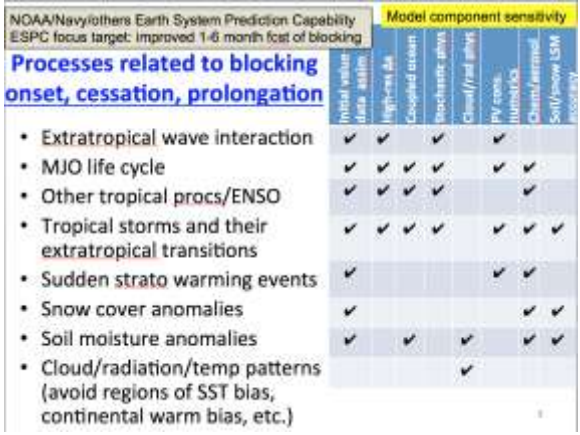
- Rerun blocking/stationary wave exps.
- Bleck et al. (2015-MWR, FIM article)

Atmos-only (AMIP) tests FIM/HYCOM coupled atmos/ocean model

- Horizontal grid
  - **Icosahedral,** Δx=30km
- Vertical grid
  - **Hybrid θ-σ** option (64L)
  - **GFS-like σ-p opt** (64L)
- Physics - 2014-GFS, Grell-Freitas scale-aware cumulus

Stationary Waves

Hypotheses on processes for onset/sustenance/cessation
Conduct research experiments for 4 stat-wave research ?s
(block predictability, Δx/numerics, process pred, physics)



Needed experiments for NMME-subseasonal community

- Frequency evaluation for blocking and % anom days/mo for extended hindcast for NMME-subseasonal (and NMME-seasonal) models.
- Experiments for YOTC, DYNAMO periods with CFSv2, FIM, (CMIP), blocking processes (MJO, SSW, etc), physics (CPT)

FIM-HYCOM AMIP/CMIP resolution/coordinate stat-wave-related experiments

- **FIM – isentropic-sigma vertical coordinate, icosahedral horizontal grid**
- **Resolution –**
  - More realistic blocking (% anomaly days/month) from higher-res (30, 60km) than coarser-res (120, 240) versions in some seasons (DJF), not in others
  - Cold bias (in 500 heights) at coarser resolution (120km, 240km)
- **Vertical coordinate** (**θ-σ** vs. **σ-p**)
  - Cold bias (in 500 heights) evident with **σ-p** coordinate, less so with **θ-σ**
  - **Hypotheses: 1) Cold bias in climate models from vertical diffusion in quasi-horizontal vertical coordinates (Johnson, 1997, *J. Climate , or***
    2) Difference in precipitation/cloud processes from different vertical coord.
  - **Improved stratospheric sudden warming with θ-σ**
  - **Improved MJO with θ-σ, 30km (vs. 60km), CMIP (vs. AMIP)**